

$b\bar{b}$ MESONS

$\Upsilon(1S)$

$$I^G(J^{PC}) = 0^-(1^{--})$$

Mass $m = 9460.30 \pm 0.26$ MeV ($S = 3.3$)

Full width $\Gamma = 54.02 \pm 1.25$ keV

$\Gamma_{ee} = 1.340 \pm 0.018$ keV

$\Upsilon(1S)$ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	P (MeV/c)
$\tau^+ \tau^-$	(2.60 \pm 0.10) %		4384
$e^+ e^-$	(2.38 \pm 0.11) %		4730
$\mu^+ \mu^-$	(2.48 \pm 0.05) %		4729

Hadronic decays

ggg	(81.7 \pm 0.7) %		—
$\gamma g g$	(2.2 \pm 0.6) %		—
$\eta'(958)$ anything	(2.94 \pm 0.24) %		—
$J/\psi(1S)$ anything	(6.5 \pm 0.7) $\times 10^{-4}$		4223
$J/\psi(1S)\eta_c$	< 2.2	$\times 10^{-6}$	90% 3623
$J/\psi(1S)\chi_{c0}$	< 3.4	$\times 10^{-6}$	90% 3429
$J/\psi(1S)\chi_{c1}$	(3.9 \pm 1.2) $\times 10^{-6}$		3382
$J/\psi(1S)\chi_{c2}$	< 1.4	$\times 10^{-6}$	90% 3359
$J/\psi(1S)\eta_c(2S)$	< 2.2	$\times 10^{-6}$	90% 3316
$J/\psi(1S)X(3940)$	< 5.4	$\times 10^{-6}$	90% 3148
$J/\psi(1S)X(4160)$	< 5.4	$\times 10^{-6}$	90% 3018
χ_{c0} anything	< 5	$\times 10^{-3}$	90% —
χ_{c1} anything	(2.3 \pm 0.7) $\times 10^{-4}$		—
χ_{c2} anything	(3.4 \pm 1.0) $\times 10^{-4}$		—
$\psi(2S)$ anything	(2.7 \pm 0.9) $\times 10^{-4}$		—
$\psi(2S)\eta_c$	< 3.6	$\times 10^{-6}$	90% 3345
$\psi(2S)\chi_{c0}$	< 6.5	$\times 10^{-6}$	90% 3124
$\psi(2S)\chi_{c1}$	< 4.5	$\times 10^{-6}$	90% 3070
$\psi(2S)\chi_{c2}$	< 2.1	$\times 10^{-6}$	90% 3043
$\psi(2S)\eta_c(2S)$	< 3.2	$\times 10^{-6}$	90% 2993
$\psi(2S)X(3940)$	< 2.9	$\times 10^{-6}$	90% 2797
$\psi(2S)X(4160)$	< 2.9	$\times 10^{-6}$	90% 2642
$\rho\pi$	< 3.68	$\times 10^{-6}$	90% 4697
$\omega\pi^0$	< 3.90	$\times 10^{-6}$	90% 4697
$\pi^+ \pi^-$	< 5	$\times 10^{-4}$	90% 4728
$K^+ K^-$	< 5	$\times 10^{-4}$	90% 4704
$p\bar{p}$	< 5	$\times 10^{-4}$	90% 4636

$\pi^+\pi^-\pi^0$	(2.1 ±0.8) × 10 ⁻⁶		4725
$\phi K^+ K^-$	(2.4 ±0.5) × 10 ⁻⁶		4622
$\omega\pi^+\pi^-$	(4.5 ±1.0) × 10 ⁻⁶		4694
$K^*(892)^0 K^- \pi^+ + \text{c.c.}$	(4.4 ±0.8) × 10 ⁻⁶		4667
$\phi f_2'(1525)$	< 1.63	× 10 ⁻⁶	90% 4549
$\omega f_2(1270)$	< 1.79	× 10 ⁻⁶	90% 4611
$\rho(770) a_2(1320)$	< 2.24	× 10 ⁻⁶	90% 4605
$K^*(892)^0 \bar{K}_2^*(1430)^0 + \text{c.c.}$	(3.0 ±0.8) × 10 ⁻⁶		4579
$K_1(1270)^\pm K^\mp$	< 2.41	× 10 ⁻⁶	90% 4631
$K_1(1400)^\pm K^\mp$	(1.0 ±0.4) × 10 ⁻⁶		4613
$b_1(1235)^\pm \pi^\mp$	< 1.25	× 10 ⁻⁶	90% 4649
$\pi^+\pi^-\pi^0\pi^0$	(1.28 ±0.30) × 10 ⁻⁵		4720
$K_S^0 K^+ \pi^- + \text{c.c.}$	(1.6 ±0.4) × 10 ⁻⁶		4696
$K^*(892)^0 \bar{K}^0 + \text{c.c.}$	(2.9 ±0.9) × 10 ⁻⁶		4675
$K^*(892)^- K^+ + \text{c.c.}$	< 1.11	× 10 ⁻⁶	90% 4675
$\bar{D}^*(2010)^\pm \text{ anything}$	(2.52 ±0.20) %		—
$\bar{d} \text{ anything}$	(2.86 ±0.28) × 10 ⁻⁵		—
Sum of 100 exclusive modes	(1.200 ±0.017) %		—

Radiative decays

$\gamma\pi^+\pi^-$	(6.3 ±1.8) × 10 ⁻⁵		4728
$\gamma\pi^0\pi^0$	(1.7 ±0.7) × 10 ⁻⁵		4728
$\gamma\pi^0\eta$	< 2.4	× 10 ⁻⁶	90% 4713
$\gamma K^+ K^-$	[a] (1.14 ±0.13) × 10 ⁻⁵		4704
$\gamma p\bar{p}$	[b] < 6	× 10 ⁻⁶	90% 4636
$\gamma 2h^+ 2h^-$	(7.0 ±1.5) × 10 ⁻⁴		4720
$\gamma 3h^+ 3h^-$	(5.4 ±2.0) × 10 ⁻⁴		4703
$\gamma 4h^+ 4h^-$	(7.4 ±3.5) × 10 ⁻⁴		4679
$\gamma\pi^+\pi^- K^+ K^-$	(2.9 ±0.9) × 10 ⁻⁴		4686
$\gamma 2\pi^+ 2\pi^-$	(2.5 ±0.9) × 10 ⁻⁴		4720
$\gamma 3\pi^+ 3\pi^-$	(2.5 ±1.2) × 10 ⁻⁴		4703
$\gamma 2\pi^+ 2\pi^- K^+ K^-$	(2.4 ±1.2) × 10 ⁻⁴		4658
$\gamma\pi^+\pi^- p\bar{p}$	(1.5 ±0.6) × 10 ⁻⁴		4604
$\gamma 2\pi^+ 2\pi^- p\bar{p}$	(4 ±6) × 10 ⁻⁵		4563
$\gamma 2K^+ 2K^-$	(2.0 ±2.0) × 10 ⁻⁵		4601
$\gamma\eta'(958)$	< 1.9	× 10 ⁻⁶	90% 4682
$\gamma\eta$	< 1.0	× 10 ⁻⁶	90% 4714
$\gamma f_0(980)$	< 3	× 10 ⁻⁵	90% 4678
$\gamma f_2'(1525)$	(3.8 ±0.9) × 10 ⁻⁵		4607
$\gamma f_2(1270)$	(1.01 ±0.09) × 10 ⁻⁴		4644
$\gamma\eta(1405)$	< 8.2	× 10 ⁻⁵	90% 4625
$\gamma f_0(1500)$	< 1.5	× 10 ⁻⁵	90% 4611
$\gamma f_0(1710)$	< 2.6	× 10 ⁻⁴	90% 4573
$\gamma f_0(1710) \rightarrow \gamma K^+ K^-$	< 7	× 10 ⁻⁶	90% —

$\gamma f_0(1710) \rightarrow \gamma \pi^0 \pi^0$	< 1.4	$\times 10^{-6}$	90%	—
$\gamma f_0(1710) \rightarrow \gamma \eta \eta$	< 1.8	$\times 10^{-6}$	90%	—
$\gamma f_4(2050)$	< 5.3	$\times 10^{-5}$	90%	4515
$\gamma f_0(2200) \rightarrow \gamma K^+ K^-$	< 2	$\times 10^{-4}$	90%	4475
$\gamma f_J(2220) \rightarrow \gamma K^+ K^-$	< 8	$\times 10^{-7}$	90%	4469
$\gamma f_J(2220) \rightarrow \gamma \pi^+ \pi^-$	< 6	$\times 10^{-7}$	90%	—
$\gamma f_J(2220) \rightarrow \gamma p \bar{p}$	< 1.1	$\times 10^{-6}$	90%	—
$\gamma \eta(2225) \rightarrow \gamma \phi \phi$	< 3	$\times 10^{-3}$	90%	4469
$\gamma \eta_c(1S)$	< 5.7	$\times 10^{-5}$	90%	4260
$\gamma \chi_{c0}$	< 6.5	$\times 10^{-4}$	90%	4114
$\gamma \chi_{c1}$	< 2.3	$\times 10^{-5}$	90%	4079
$\gamma \chi_{c2}$	< 7.6	$\times 10^{-6}$	90%	4062
$\gamma X(3872) \rightarrow \pi^+ \pi^- J/\psi$	< 1.6	$\times 10^{-6}$	90%	—
$\gamma X(3872) \rightarrow \pi^+ \pi^- \pi^0 J/\psi$	< 2.8	$\times 10^{-6}$	90%	—
$\gamma \chi_{c0}(3915) \rightarrow \omega J/\psi$	< 3.0	$\times 10^{-6}$	90%	—
$\gamma X(4140) \rightarrow \phi J/\psi$	< 2.2	$\times 10^{-6}$	90%	—
γX	[c] < 4.5	$\times 10^{-6}$	90%	—
$\gamma X \bar{X} (m_X < 3.1 \text{ GeV})$	[d] < 1	$\times 10^{-3}$	90%	—
$\gamma X \bar{X} (m_X < 4.5 \text{ GeV})$	[e] < 2.4	$\times 10^{-4}$	90%	—
$\gamma X \rightarrow \gamma + \geq 4 \text{ prongs}$	[f] < 1.78	$\times 10^{-4}$	95%	—
$\gamma a_1^0 \rightarrow \gamma \mu^+ \mu^-$	[g] < 9	$\times 10^{-6}$	90%	—
$\gamma a_1^0 \rightarrow \gamma \tau^+ \tau^-$	[a] < 1.30	$\times 10^{-4}$	90%	—
$\gamma a_1^0 \rightarrow \gamma g g$	[h] < 1	%	90%	—
$\gamma a_1^0 \rightarrow \gamma s \bar{s}$	[h] < 1	$\times 10^{-3}$	90%	—

Lepton Family number (LF) violating modes

$\mu^\pm \tau^\mp$	LF	< 6.0	$\times 10^{-6}$	95%	4563
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Other decays

invisible	< 3.0	$\times 10^{-4}$	90%	—
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$\chi_{b0}(1P)$ [i]

$$J^G(J^{PC}) = 0^+(0^{++})$$

J needs confirmation.

$$\text{Mass } m = 9859.44 \pm 0.42 \pm 0.31 \text{ MeV}$$

$\chi_{b0}(1P)$ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	P (MeV/c)
$\gamma \Upsilon(1S)$	(1.76 ± 0.35) %		391
$D^0 X$	< 10.4	%	90%
$\pi^+ \pi^- K^+ K^- \pi^0$	< 1.6	$\times 10^{-4}$	90%
$2\pi^+ \pi^- K^- K_S^0$	< 5	$\times 10^{-5}$	90%
$2\pi^+ \pi^- K^- K_S^0 2\pi^0$	< 5	$\times 10^{-4}$	90%
$2\pi^+ 2\pi^- 2\pi^0$	< 2.1	$\times 10^{-4}$	90%
$2\pi^+ 2\pi^- K^+ K^-$	(1.1 ± 0.6) $\times 10^{-4}$		4861

$2\pi^+ 2\pi^- K^+ K^- \pi^0$	< 2.7	$\times 10^{-4}$	90%	4846
$2\pi^+ 2\pi^- K^+ K^- 2\pi^0$	< 5	$\times 10^{-4}$	90%	4828
$3\pi^+ 2\pi^- K^- K_S^0 \pi^0$	< 1.6	$\times 10^{-4}$	90%	4827
$3\pi^+ 3\pi^-$	< 8	$\times 10^{-5}$	90%	4904
$3\pi^+ 3\pi^- 2\pi^0$	< 6	$\times 10^{-4}$	90%	4881
$3\pi^+ 3\pi^- K^+ K^-$	(2.4 ± 1.2)	$\times 10^{-4}$		4827
$3\pi^+ 3\pi^- K^+ K^- \pi^0$	< 1.0	$\times 10^{-3}$	90%	4808
$4\pi^+ 4\pi^-$	< 8	$\times 10^{-5}$	90%	4880
$4\pi^+ 4\pi^- 2\pi^0$	< 2.1	$\times 10^{-3}$	90%	4850
$J/\psi J/\psi$	< 7	$\times 10^{-5}$	90%	3836
$J/\psi \psi(2S)$	< 1.2	$\times 10^{-4}$	90%	3571
$\psi(2S) \psi(2S)$	< 3.1	$\times 10^{-5}$	90%	3273

$\chi_{b1}(1P)$ ^[i]

$I^G(J^{PC}) = 0^+(1^{++})$
J needs confirmation.

Mass $m = 9892.78 \pm 0.26 \pm 0.31$ MeV

$\chi_{b1}(1P)$ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	P (MeV/c)
$\gamma \Upsilon(1S)$	$(33.9 \pm 2.2) \%$		423
$D^0 X$	$(12.6 \pm 2.2) \%$		—
$\pi^+ \pi^- K^+ K^- \pi^0$	$(2.0 \pm 0.6) \times 10^{-4}$		4892
$2\pi^+ \pi^- K^- K_S^0$	$(1.3 \pm 0.5) \times 10^{-4}$		4892
$2\pi^+ \pi^- K^- K_S^0 2\pi^0$	$< 6 \times 10^{-4}$	90%	4863
$2\pi^+ 2\pi^- 2\pi^0$	$(8.0 \pm 2.5) \times 10^{-4}$		4921
$2\pi^+ 2\pi^- K^+ K^-$	$(1.5 \pm 0.5) \times 10^{-4}$		4878
$2\pi^+ 2\pi^- K^+ K^- \pi^0$	$(3.5 \pm 1.2) \times 10^{-4}$		4863
$2\pi^+ 2\pi^- K^+ K^- 2\pi^0$	$(8.6 \pm 3.2) \times 10^{-4}$		4845
$3\pi^+ 2\pi^- K^- K_S^0 \pi^0$	$(9.3 \pm 3.3) \times 10^{-4}$		4844
$3\pi^+ 3\pi^-$	$(1.9 \pm 0.6) \times 10^{-4}$		4921
$3\pi^+ 3\pi^- 2\pi^0$	$(1.7 \pm 0.5) \times 10^{-3}$		4898
$3\pi^+ 3\pi^- K^+ K^-$	$(2.6 \pm 0.8) \times 10^{-4}$		4844
$3\pi^+ 3\pi^- K^+ K^- \pi^0$	$(7.5 \pm 2.6) \times 10^{-4}$		4825
$4\pi^+ 4\pi^-$	$(2.6 \pm 0.9) \times 10^{-4}$		4897
$4\pi^+ 4\pi^- 2\pi^0$	$(1.4 \pm 0.6) \times 10^{-3}$		4867
$J/\psi J/\psi$	$< 2.7 \times 10^{-5}$	90%	3857
$J/\psi \psi(2S)$	$< 1.7 \times 10^{-5}$	90%	3594
$\psi(2S) \psi(2S)$	$< 6 \times 10^{-5}$	90%	3298

$h_b(1P)$

$$I^G(J^{PC}) = ??(1^{+-})$$

Mass $m = 9899.3 \pm 1.0$ MeV

$h_b(1P)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\eta_b(1S)\gamma$	$(49_{-7}^{+8})\%$	489

$\chi_{b2}(1P)$ [i]

$$I^G(J^{PC}) = 0^+(2^{++})$$

J needs confirmation.

Mass $m = 9912.21 \pm 0.26 \pm 0.31$ MeV

$\chi_{b2}(1P)$ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$\gamma \Upsilon(1S)$	$(19.1 \pm 1.2)\%$		442
$D^0 X$	$< 7.9\%$	90%	—
$\pi^+ \pi^- K^+ K^- \pi^0$	$(8 \pm 5) \times 10^{-5}$		4902
$2\pi^+ \pi^- K^- K_S^0$	$< 1.0 \times 10^{-4}$	90%	4901
$2\pi^+ \pi^- K^- K_S^0 2\pi^0$	$(5.3 \pm 2.4) \times 10^{-4}$		4873
$2\pi^+ 2\pi^- 2\pi^0$	$(3.5 \pm 1.4) \times 10^{-4}$		4931
$2\pi^+ 2\pi^- K^+ K^-$	$(1.1 \pm 0.4) \times 10^{-4}$		4888
$2\pi^+ 2\pi^- K^+ K^- \pi^0$	$(2.1 \pm 0.9) \times 10^{-4}$		4872
$2\pi^+ 2\pi^- K^+ K^- 2\pi^0$	$(3.9 \pm 1.8) \times 10^{-4}$		4855
$3\pi^+ 2\pi^- K^- K_S^0 \pi^0$	$< 5 \times 10^{-4}$	90%	4854
$3\pi^+ 3\pi^-$	$(7.0 \pm 3.1) \times 10^{-5}$		4931
$3\pi^+ 3\pi^- 2\pi^0$	$(1.0 \pm 0.4) \times 10^{-3}$		4908
$3\pi^+ 3\pi^- K^+ K^-$	$< 8 \times 10^{-5}$	90%	4854
$3\pi^+ 3\pi^- K^+ K^- \pi^0$	$(3.6 \pm 1.5) \times 10^{-4}$		4835
$4\pi^+ 4\pi^-$	$(8 \pm 4) \times 10^{-5}$		4907
$4\pi^+ 4\pi^- 2\pi^0$	$(1.8 \pm 0.7) \times 10^{-3}$		4877
$J/\psi J/\psi$	$< 4 \times 10^{-5}$	90%	3869
$J/\psi \psi(2S)$	$< 5 \times 10^{-5}$	90%	3608
$\psi(2S) \psi(2S)$	$< 1.6 \times 10^{-5}$	90%	3313

$\Upsilon(2S)$

$$I^G(J^{PC}) = 0^-(1^{--})$$

Mass $m = 10023.26 \pm 0.31$ MeV

$m_{\Upsilon(3S)} - m_{\Upsilon(2S)} = 331.50 \pm 0.13$ MeV

Full width $\Gamma = 31.98 \pm 2.63$ keV

$\Gamma_{ee} = 0.612 \pm 0.011$ keV

$\Upsilon(2S)$ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
$\Upsilon(1S)\pi^+\pi^-$	$(17.85 \pm 0.26) \%$		475
$\Upsilon(1S)\pi^0\pi^0$	$(8.6 \pm 0.4) \%$		480
$\tau^+\tau^-$	$(2.00 \pm 0.21) \%$		4686
$\mu^+\mu^-$	$(1.93 \pm 0.17) \%$	S=2.2	5011
e^+e^-	$(1.91 \pm 0.16) \%$		5012
$\Upsilon(1S)\pi^0$	< 4	$\times 10^{-5}$ CL=90%	531
$\Upsilon(1S)\eta$	$(2.9 \pm 0.4) \times 10^{-4}$	S=2.0	126
$J/\psi(1S)$ anything	< 6	$\times 10^{-3}$ CL=90%	4533
$J/\psi(1S)\eta_c$	< 5.4	$\times 10^{-6}$ CL=90%	3984
$J/\psi(1S)\chi_{c0}$	< 3.4	$\times 10^{-6}$ CL=90%	3808
$J/\psi(1S)\chi_{c1}$	< 1.2	$\times 10^{-6}$ CL=90%	3765
$J/\psi(1S)\chi_{c2}$	< 2.0	$\times 10^{-6}$ CL=90%	3744
$J/\psi(1S)\eta_c(2S)$	< 2.5	$\times 10^{-6}$ CL=90%	3706
$J/\psi(1S)X(3940)$	< 2.0	$\times 10^{-6}$ CL=90%	3555
$J/\psi(1S)X(4160)$	< 2.0	$\times 10^{-6}$ CL=90%	3440
$\psi(2S)\eta_c$	< 5.1	$\times 10^{-6}$ CL=90%	3732
$\psi(2S)\chi_{c0}$	< 4.7	$\times 10^{-6}$ CL=90%	3536
$\psi(2S)\chi_{c1}$	< 2.5	$\times 10^{-6}$ CL=90%	3488
$\psi(2S)\chi_{c2}$	< 1.9	$\times 10^{-6}$ CL=90%	3464
$\psi(2S)\eta_c(2S)$	< 3.3	$\times 10^{-6}$ CL=90%	3421
$\psi(2S)X(3940)$	< 3.9	$\times 10^{-6}$ CL=90%	3250
$\psi(2S)X(4160)$	< 3.9	$\times 10^{-6}$ CL=90%	3118
d anything	$(3.4 \pm 0.6) \times 10^{-5}$		–
hadrons	$(94 \pm 11) \%$		–
ggg	$(58.8 \pm 1.2) \%$		–
γgg	$(8.8 \pm 1.1) \%$		–
ϕK^+K^-	$(1.6 \pm 0.4) \times 10^{-6}$		4910
$\omega\pi^+\pi^-$	< 2.58	$\times 10^{-6}$ CL=90%	4977
$K^*(892)^0 K^-\pi^+ + c.c.$	$(2.3 \pm 0.7) \times 10^{-6}$		4952
$\phi f'_2(1525)$	< 1.33	$\times 10^{-6}$ CL=90%	4841
$\omega f_2(1270)$	< 5.7	$\times 10^{-7}$ CL=90%	4899
$\rho(770)a_2(1320)$	< 8.8	$\times 10^{-7}$ CL=90%	4894
$K^*(892)^0 \bar{K}_2^*(1430)^0 + c.c.$	$(1.5 \pm 0.6) \times 10^{-6}$		4869
$K_1(1270)^\pm K^\mp$	< 3.22	$\times 10^{-6}$ CL=90%	4918
$K_1(1400)^\pm K^\mp$	< 8.3	$\times 10^{-7}$ CL=90%	4901
$b_1(1235)^\pm \pi^\mp$	< 4.0	$\times 10^{-7}$ CL=90%	4935
$\rho\pi$	< 1.16	$\times 10^{-6}$ CL=90%	4981
$\pi^+\pi^-\pi^0$	< 8.0	$\times 10^{-7}$ CL=90%	5007
$\omega\pi^0$	< 1.63	$\times 10^{-6}$ CL=90%	4980
$\pi^+\pi^-\pi^0\pi^0$	$(1.30 \pm 0.28) \times 10^{-5}$		5002
$K_S^0 K^+\pi^- + c.c.$	$(1.14 \pm 0.33) \times 10^{-6}$		4979

$K^*(892)^0 \bar{K}^0 + \text{c.c.}$	< 4.22	$\times 10^{-6}$	CL=90%	4959
$K^*(892)^- K^+ + \text{c.c.}$	< 1.45	$\times 10^{-6}$	CL=90%	4960
Sum of 100 exclusive modes	(2.90 ± 0.30)	$\times 10^{-3}$		—

Radiative decays

$\gamma \chi_{b1}(1P)$	(6.9 ± 0.4)	%		130
$\gamma \chi_{b2}(1P)$	(7.15 ± 0.35)	%		110
$\gamma \chi_{b0}(1P)$	(3.8 ± 0.4)	%		162
$\gamma f_0(1710)$	< 5.9	$\times 10^{-4}$	CL=90%	4864
$\gamma f'_2(1525)$	< 5.3	$\times 10^{-4}$	CL=90%	4896
$\gamma f_2(1270)$	< 2.41	$\times 10^{-4}$	CL=90%	4930
$\gamma \eta_c(1S)$	< 2.7	$\times 10^{-5}$	CL=90%	4568
$\gamma \chi_{c0}$	< 1.0	$\times 10^{-4}$	CL=90%	4430
$\gamma \chi_{c1}$	< 3.6	$\times 10^{-6}$	CL=90%	4397
$\gamma \chi_{c2}$	< 1.5	$\times 10^{-5}$	CL=90%	4381
$\gamma X(3872) \rightarrow \pi^+ \pi^- J/\psi$	< 8	$\times 10^{-7}$	CL=90%	—
$\gamma X(3872) \rightarrow \pi^+ \pi^- \pi^0 J/\psi$	< 2.4	$\times 10^{-6}$	CL=90%	—
$\gamma \chi_{c0}(3915) \rightarrow \omega J/\psi$	< 2.8	$\times 10^{-6}$	CL=90%	—
$\gamma X(4140) \rightarrow \phi J/\psi$	< 1.2	$\times 10^{-6}$	CL=90%	—
$\gamma X(4350) \rightarrow \phi J/\psi$	< 1.3	$\times 10^{-6}$	CL=90%	—
$\gamma \eta_b(1S)$	(3.9 ± 1.5)	$\times 10^{-4}$		606
$\gamma \eta_b(1S) \rightarrow \gamma$ Sum of 26 exclusive modes	< 3.7	$\times 10^{-6}$	CL=90%	—
$\gamma X_{b\bar{b}} \rightarrow \gamma$ Sum of 26 exclusive modes	< 4.9	$\times 10^{-6}$	CL=90%	—
$\gamma X \rightarrow \gamma + \geq 4$ prongs	$[j] < 1.95$	$\times 10^{-4}$	CL=95%	—
$\gamma A^0 \rightarrow \gamma$ hadrons	< 8	$\times 10^{-5}$	CL=90%	—
$\gamma a_1^0 \rightarrow \gamma \mu^+ \mu^-$	< 8.3	$\times 10^{-6}$	CL=90%	—

Lepton Family number (LF) violating modes

$e^\pm \tau^\mp$	LF	< 3.2	$\times 10^{-6}$	CL=90%	4854
$\mu^\pm \tau^\mp$	LF	< 3.3	$\times 10^{-6}$	CL=90%	4854

$\Upsilon(1D)$

$$I^G(J^{PC}) = 0^-(2^{--})$$

Mass $m = 10163.7 \pm 1.4$ MeV (S = 1.7)

$\Upsilon(1D)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\gamma\gamma \Upsilon(1S)$	seen	679
$\gamma \chi_{bJ}(1P)$	seen	300
$\eta \Upsilon(1S)$	not seen	426
$\pi^+ \pi^- \Upsilon(1S)$	$(6.6 \pm 1.6) \times 10^{-3}$	623

$\chi_{b0}(2P)$ [i]

$$J^G(J^{PC}) = 0^+(0^{++})$$

J needs confirmation.

$$\text{Mass } m = 10232.5 \pm 0.4 \pm 0.5 \text{ MeV}$$

$\chi_{b0}(2P)$ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	P (MeV/c)
$\gamma \Upsilon(2S)$	$(4.6 \pm 2.1) \%$		207
$\gamma \Upsilon(1S)$	$(9 \pm 6) \times 10^{-3}$		743
$D^0 X$	$< 8.2 \%$	90%	—
$\pi^+ \pi^- K^+ K^- \pi^0$	$< 3.4 \times 10^{-5}$	90%	5064
$2\pi^+ \pi^- K^- K_S^0$	$< 5 \times 10^{-5}$	90%	5063
$2\pi^+ \pi^- K^- K_S^0 2\pi^0$	$< 2.2 \times 10^{-4}$	90%	5036
$2\pi^+ 2\pi^- 2\pi^0$	$< 2.4 \times 10^{-4}$	90%	5092
$2\pi^+ 2\pi^- K^+ K^-$	$< 1.5 \times 10^{-4}$	90%	5050
$2\pi^+ 2\pi^- K^+ K^- \pi^0$	$< 2.2 \times 10^{-4}$	90%	5035
$2\pi^+ 2\pi^- K^+ K^- 2\pi^0$	$< 1.1 \times 10^{-3}$	90%	5019
$3\pi^+ 2\pi^- K^- K_S^0 \pi^0$	$< 7 \times 10^{-4}$	90%	5018
$3\pi^+ 3\pi^-$	$< 7 \times 10^{-5}$	90%	5091
$3\pi^+ 3\pi^- 2\pi^0$	$< 1.2 \times 10^{-3}$	90%	5070
$3\pi^+ 3\pi^- K^+ K^-$	$< 1.5 \times 10^{-4}$	90%	5017
$3\pi^+ 3\pi^- K^+ K^- \pi^0$	$< 7 \times 10^{-4}$	90%	4999
$4\pi^+ 4\pi^-$	$< 1.7 \times 10^{-4}$	90%	5069
$4\pi^+ 4\pi^- 2\pi^0$	$< 6 \times 10^{-4}$	90%	5039

$\chi_{b1}(2P)$ [i]

$$J^G(J^{PC}) = 0^+(1^{++})$$

J needs confirmation.

$$\text{Mass } m = 10255.46 \pm 0.22 \pm 0.50 \text{ MeV}$$

$$m_{\chi_{b1}(2P)} - m_{\chi_{b0}(2P)} = 23.5 \pm 1.0 \text{ MeV}$$

$\chi_{b1}(2P)$ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor	P (MeV/c)
$\omega \Upsilon(1S)$	$(1.63^{+0.40}_{-0.34}) \%$		135
$\gamma \Upsilon(2S)$	$(19.9 \pm 1.9) \%$		230
$\gamma \Upsilon(1S)$	$(9.2 \pm 0.8) \%$	1.1	764
$\pi\pi \chi_{b1}(1P)$	$(9.1 \pm 1.3) \times 10^{-3}$		238
$D^0 X$	$(8.8 \pm 1.7) \%$		—
$\pi^+ \pi^- K^+ K^- \pi^0$	$(3.1 \pm 1.0) \times 10^{-4}$		5075
$2\pi^+ \pi^- K^- K_S^0$	$(1.1 \pm 0.5) \times 10^{-4}$		5075
$2\pi^+ \pi^- K^- K_S^0 2\pi^0$	$(7.7 \pm 3.2) \times 10^{-4}$		5047
$2\pi^+ 2\pi^- 2\pi^0$	$(5.9 \pm 2.0) \times 10^{-4}$		5104

$2\pi^+ 2\pi^- K^+ K^-$	$(10 \pm 4) \times 10^{-5}$	5062
$2\pi^+ 2\pi^- K^+ K^- \pi^0$	$(5.5 \pm 1.8) \times 10^{-4}$	5047
$2\pi^+ 2\pi^- K^+ K^- 2\pi^0$	$(10 \pm 4) \times 10^{-4}$	5030
$3\pi^+ 2\pi^- K^- K_S^0 \pi^0$	$(6.7 \pm 2.6) \times 10^{-4}$	5029
$3\pi^+ 3\pi^-$	$(1.2 \pm 0.4) \times 10^{-4}$	5103
$3\pi^+ 3\pi^- 2\pi^0$	$(1.2 \pm 0.4) \times 10^{-3}$	5081
$3\pi^+ 3\pi^- K^+ K^-$	$(2.0 \pm 0.8) \times 10^{-4}$	5029
$3\pi^+ 3\pi^- K^+ K^- \pi^0$	$(6.1 \pm 2.2) \times 10^{-4}$	5011
$4\pi^+ 4\pi^-$	$(1.7 \pm 0.6) \times 10^{-4}$	5080
$4\pi^+ 4\pi^- 2\pi^0$	$(1.9 \pm 0.7) \times 10^{-3}$	5051

$\chi_{b2}(2P)$ [i]

$$I^G(J^{PC}) = 0^+(2^{++})$$

J needs confirmation.

$$\text{Mass } m = 10268.65 \pm 0.22 \pm 0.50 \text{ MeV}$$

$$m_{\chi_{b2}(2P)} - m_{\chi_{b1}(2P)} = 13.4 \pm 0.6 \text{ MeV}$$

$\chi_{b2}(2P)$ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
$\omega \Upsilon(1S)$	$(1.10^{+0.34}_{-0.30})\%$		194
$\gamma \Upsilon(2S)$	$(10.6 \pm 2.6)\%$	S=2.0	242
$\gamma \Upsilon(1S)$	$(7.0 \pm 0.7)\%$		777
$\pi\pi \chi_{b2}(1P)$	$(5.1 \pm 0.9) \times 10^{-3}$		229
$D^0 X$	$< 2.4\%$	CL=90%	—
$\pi^+ \pi^- K^+ K^- \pi^0$	$< 1.1 \times 10^{-4}$	CL=90%	5082
$2\pi^+ \pi^- K^- K_S^0$	$< 9 \times 10^{-5}$	CL=90%	5082
$2\pi^+ \pi^- K^- K_S^0 2\pi^0$	$< 7 \times 10^{-4}$	CL=90%	5054
$2\pi^+ 2\pi^- 2\pi^0$	$(3.9 \pm 1.6) \times 10^{-4}$		5110
$2\pi^+ 2\pi^- K^+ K^-$	$(9 \pm 4) \times 10^{-5}$		5068
$2\pi^+ 2\pi^- K^+ K^- \pi^0$	$(2.4 \pm 1.1) \times 10^{-4}$		5054
$2\pi^+ 2\pi^- K^+ K^- 2\pi^0$	$(4.7 \pm 2.3) \times 10^{-4}$		5037
$3\pi^+ 2\pi^- K^- K_S^0 \pi^0$	$< 4 \times 10^{-4}$	CL=90%	5036
$3\pi^+ 3\pi^-$	$(9 \pm 4) \times 10^{-5}$		5110
$3\pi^+ 3\pi^- 2\pi^0$	$(1.2 \pm 0.4) \times 10^{-3}$		5088
$3\pi^+ 3\pi^- K^+ K^-$	$(1.4 \pm 0.7) \times 10^{-4}$		5036
$3\pi^+ 3\pi^- K^+ K^- \pi^0$	$(4.2 \pm 1.7) \times 10^{-4}$		5017
$4\pi^+ 4\pi^-$	$(9 \pm 5) \times 10^{-5}$		5087
$4\pi^+ 4\pi^- 2\pi^0$	$(1.3 \pm 0.5) \times 10^{-3}$		5058

$\Upsilon(3S)$

$$J^{PC} = 0^{-}(1^{- -})$$

Mass $m = 10355.2 \pm 0.5$ MeV
 $m_{\Upsilon(3S)} - m_{\Upsilon(2S)} = 331.50 \pm 0.13$ MeV
 Full width $\Gamma = 20.32 \pm 1.85$ keV
 $\Gamma_{ee} = 0.443 \pm 0.008$ keV

$\Upsilon(3S)$ DECAY MODES	Fraction (Γ_i/Γ)	Scale factor/ Confidence level	p (MeV/c)
$\Upsilon(2S)$ anything	(10.6 \pm 0.8) %		296
$\Upsilon(2S)\pi^+\pi^-$	(2.82 \pm 0.18) %	S=1.6	177
$\Upsilon(2S)\pi^0\pi^0$	(1.85 \pm 0.14) %		190
$\Upsilon(2S)\gamma\gamma$	(5.0 \pm 0.7) %		327
$\Upsilon(2S)\pi^0$	< 5.1 $\times 10^{-4}$	CL=90%	298
$\Upsilon(1S)\pi^+\pi^-$	(4.37 \pm 0.08) %		813
$\Upsilon(1S)\pi^0\pi^0$	(2.20 \pm 0.13) %		816
$\Upsilon(1S)\eta$	< 1 $\times 10^{-4}$	CL=90%	677
$\Upsilon(1S)\pi^0$	< 7 $\times 10^{-5}$	CL=90%	846
$h_b(1P)\pi^0$	< 1.2 $\times 10^{-3}$	CL=90%	426
$h_b(1P)\pi^0 \rightarrow \gamma\eta_b(1S)\pi^0$	(4.3 \pm 1.4) $\times 10^{-4}$		—
$h_b(1P)\pi^+\pi^-$	< 1.2 $\times 10^{-4}$	CL=90%	353
$\tau^+\tau^-$	(2.29 \pm 0.30) %		4863
$\mu^+\mu^-$	(2.18 \pm 0.21) %	S=2.1	5177
e^+e^-	seen		5178
ggg	(35.7 \pm 2.6) %		—
γgg	(9.7 \pm 1.8) $\times 10^{-3}$		—

Radiative decays

$\gamma\chi_{b2}(2P)$	(13.1 \pm 1.6) %	S=3.4	86
$\gamma\chi_{b1}(2P)$	(12.6 \pm 1.2) %	S=2.4	99
$\gamma\chi_{b0}(2P)$	(5.9 \pm 0.6) %	S=1.4	122
$\gamma\chi_{b2}(1P)$	(9.9 \pm 1.3) $\times 10^{-3}$	S=2.0	434
$\gamma A^0 \rightarrow \gamma$ hadrons	< 8 $\times 10^{-5}$	CL=90%	—
$\gamma\chi_{b1}(1P)$	(9 \pm 5) $\times 10^{-4}$	S=1.9	452
$\gamma\chi_{b0}(1P)$	(2.7 \pm 0.4) $\times 10^{-3}$		484
$\gamma\eta_b(2S)$	< 6.2 $\times 10^{-4}$	CL=90%	350
$\gamma\eta_b(1S)$	(5.1 \pm 0.7) $\times 10^{-4}$		913
$\gamma X \rightarrow \gamma + \geq 4$ prongs	[k] < 2.2 $\times 10^{-4}$	CL=95%	—
$\gamma a_1^0 \rightarrow \gamma\mu^+\mu^-$	< 5.5 $\times 10^{-6}$	CL=90%	—
$\gamma a_1^0 \rightarrow \gamma\tau^+\tau^-$	[l] < 1.6 $\times 10^{-4}$	CL=90%	—

Lepton Family number (LF) violating modes

$e^\pm\tau^\mp$	LF	< 4.2 $\times 10^{-6}$	CL=90%	5025
$\mu^\pm\tau^\mp$	LF	< 3.1 $\times 10^{-6}$	CL=90%	5025

$\chi_{b1}(3P)$

$$J^{PC} = 0^+(1^{++})$$

Mass $m = 10512.1 \pm 2.3$ MeV

$\chi_{b1}(3P)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\Upsilon(1S)\gamma$	seen	999
$\Upsilon(2S)\gamma$	seen	477
$\Upsilon(3S)\gamma$	seen	156

**$\Upsilon(4S)$
or $\Upsilon(10580)$**

$$J^{PC} = 0^-(1^{--})$$

Mass $m = 10579.4 \pm 1.2$ MeV

Full width $\Gamma = 20.5 \pm 2.5$ MeV

$\Gamma_{ee} = 0.272 \pm 0.029$ keV ($S = 1.5$)

$\Upsilon(4S)$ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$B\bar{B}$	> 96 %	95%	326
B^+B^-	(51.4 ± 0.6) %		330
D_S^+ anything + c.c.	(17.8 ± 2.6) %		—
$B^0\bar{B}^0$	(48.6 ± 0.6) %		326
$J/\psi K_S^0(J/\psi, \eta_c)K_S^0$	< 4 × 10 ⁻⁷	90%	—
non- $B\bar{B}$	< 4 %	95%	—
e^+e^-	(1.57 ± 0.08) × 10 ⁻⁵		5290
$\rho^+\rho^-$	< 5.7 × 10 ⁻⁶	90%	5233
$K^*(892)^0\bar{K}^0$	< 2.0 × 10 ⁻⁶	90%	5240
$J/\psi(1S)$ anything	< 1.9 × 10 ⁻⁴	95%	—
D^{*+} anything + c.c.	< 7.4 %	90%	5099
ϕ anything	(7.1 ± 0.6) %		5240
$\phi\eta$	< 1.8 × 10 ⁻⁶	90%	5226
$\phi\eta'$	< 4.3 × 10 ⁻⁶	90%	5196
$\rho\eta$	< 1.3 × 10 ⁻⁶	90%	5247
$\rho\eta'$	< 2.5 × 10 ⁻⁶	90%	5217
$\Upsilon(1S)$ anything	< 4 × 10 ⁻³	90%	1053
$\Upsilon(1S)\pi^+\pi^-$	(8.1 ± 0.6) × 10 ⁻⁵		1026
$\Upsilon(1S)\eta$	(1.96 ± 0.28) × 10 ⁻⁴		924
$\Upsilon(2S)\pi^+\pi^-$	(8.6 ± 1.3) × 10 ⁻⁵		468
$h_b(1P)\pi^+\pi^-$	not seen		600
\bar{d} anything	< 1.3 × 10 ⁻⁵	90%	—

$\Upsilon(10860)$

$$J^{PC} = 0^-(1^{--})$$

Mass $m = 10876 \pm 11$ MeV

Full width $\Gamma = 55 \pm 28$ MeV

$\Gamma_{ee} = 0.31 \pm 0.07$ keV ($S = 1.3$)

$\Upsilon(10860)$ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	P (MeV/c)
$B\bar{B}X$	(76.2 $^{+2.7}_{-4.0}$) %		—
$B\bar{B}$	(5.5 ± 1.0) %		1303
$B\bar{B}^* + c.c.$	(13.7 ± 1.6) %		—
$B^*\bar{B}^*$	(38.1 ± 3.4) %		1130
$B\bar{B}^{(*)}\pi$	< 19.7 %	90%	990
$B\bar{B}\pi$	(0.0 ± 1.2) %		990
$B^*\bar{B}\pi + B\bar{B}^*\pi$	(7.3 ± 2.3) %		—
$B^*\bar{B}^*\pi$	(1.0 ± 1.4) %		744
$B\bar{B}\pi\pi$	< 8.9 %	90%	504
$B_s^{(*)}\bar{B}_s^{(*)}$	(20.1 ± 3.1) %		877
$B_s\bar{B}_s$	(5 ± 5) $\times 10^{-3}$		877
$B_s\bar{B}_s^* + c.c.$	(1.35 ± 0.32) %		—
$B_s^*\bar{B}_s^*$	(17.6 ± 2.7) %		495
no open-bottom	(3.8 $^{+5.0}_{-0.5}$) %		—
e^+e^-	(5.6 ± 3.1) $\times 10^{-6}$		5438
$K^*(892)^0\bar{K}^0$	< 1.0 $\times 10^{-5}$	90%	5390
$\Upsilon(1S)\pi^+\pi^-$	(5.3 ± 0.6) $\times 10^{-3}$		1297
$\Upsilon(2S)\pi^+\pi^-$	(7.8 ± 1.3) $\times 10^{-3}$		774
$\Upsilon(3S)\pi^+\pi^-$	(4.8 $^{+1.9}_{-1.7}$) $\times 10^{-3}$		429
$\Upsilon(1S)K^+K^-$	(6.1 ± 1.8) $\times 10^{-4}$		947
$h_b(1P)\pi^+\pi^-$	(3.5 $^{+1.0}_{-1.3}$) $\times 10^{-3}$		894
$h_b(2P)\pi^+\pi^-$	(6.0 $^{+2.1}_{-1.8}$) $\times 10^{-3}$		534
$\chi_{b0}(1P)\pi^+\pi^-\pi^0$	< 6.3 $\times 10^{-3}$	90%	885
$\chi_{b0}(1P)\omega$	< 3.9 $\times 10^{-3}$	90%	618
$\chi_{b0}(1P)(\pi^+\pi^-\pi^0)_{\text{non-}\omega}$	< 4.8 $\times 10^{-3}$	90%	—
$\chi_{b1}(1P)\pi^+\pi^-\pi^0$	(1.85 ± 0.33) $\times 10^{-3}$		851
$\chi_{b1}(1P)\omega$	(1.57 ± 0.30) $\times 10^{-3}$		568
$\chi_{b1}(1P)(\pi^+\pi^-\pi^0)_{\text{non-}\omega}$	(5.2 ± 1.9) $\times 10^{-4}$		—
$\chi_{b2}(1P)\pi^+\pi^-\pi^0$	(1.17 ± 0.30) $\times 10^{-3}$		832
$\chi_{b2}(1P)\omega$	(6.0 ± 2.7) $\times 10^{-4}$		537
$\chi_{b2}(1P)(\pi^+\pi^-\pi^0)_{\text{non-}\omega}$	(6 ± 4) $\times 10^{-4}$		—
$\gamma\chi_b \rightarrow \gamma\Upsilon(1S)\omega$	< 3.8 $\times 10^{-5}$	90%	—

Inclusive Decays.

These decay modes are submodes of one or more of the decay modes above.

ϕ anything	(13.8 $^{+2.4}_{-1.7}$) %	–
D^0 anything + c.c.	(108 ± 8) %	–
D_s anything + c.c.	(46 ± 6) %	–
J/ψ anything	(2.06 ± 0.21) %	–
B^0 anything + c.c.	(77 ± 8) %	–
B^+ anything + c.c.	(72 ± 6) %	–

$\Upsilon(11020)$

$$I^G(J^{PC}) = 0^-(1^{--})$$

Mass $m = 11019 \pm 8$ MeV

Full width $\Gamma = 79 \pm 16$ MeV

$\Gamma_{ee} = 0.130 \pm 0.030$ keV

$\Upsilon(11020)$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$e^+ e^-$	$(1.6 \pm 0.5) \times 10^{-6}$	5510

NOTES

[a] $2m_\tau < M(\tau^+ \tau^-) < 9.2$ GeV

[b] 2 GeV $< m_{K^+ K^-} < 3$ GeV

[c] $X =$ scalar with $m < 8.0$ GeV

[d] $X \bar{X} =$ vectors with $m < 3.1$ GeV

[e] X and $\bar{X} =$ zero spin with $m < 4.5$ GeV

[f] 1.5 GeV $< m_X < 5.0$ GeV

[g] 201 MeV $< M(\mu^+ \mu^-) < 3565$ MeV

[h] 0.5 GeV $< m_X < 9.0$ GeV, where m_X is the invariant mass of the hadronic final state.

[i] Spectroscopic labeling for these states is theoretical, pending experimental information.

[j] 1.5 GeV $< m_X < 5.0$ GeV

[k] 1.5 GeV $< m_X < 5.0$ GeV

[l] For $m_{\tau^+ \tau^-}$ in the ranges 4.03–9.52 and 9.61–10.10 GeV.